Standard candles

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What is a 'standard candle'?

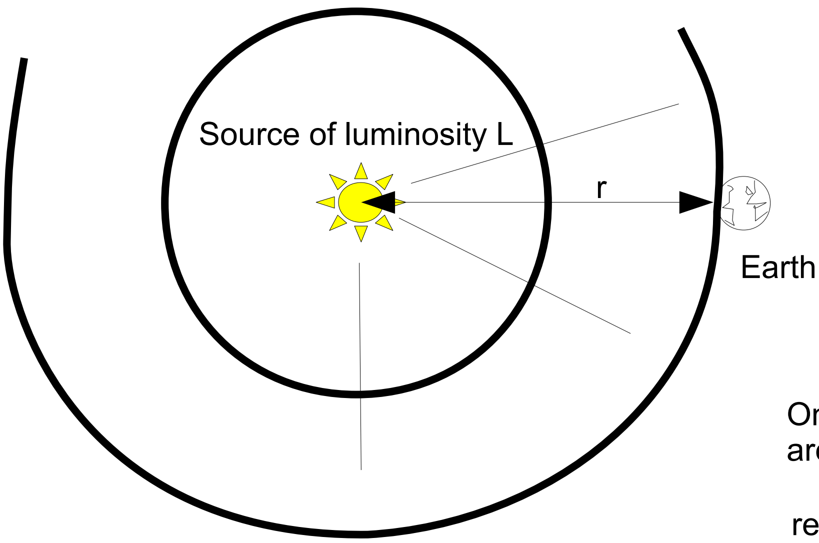


In astronomy, a **standard candle** is a source that has a known **luminosity.**
luminosity = total power output, measured in watts (W) or solar luminosities ($L_\odot$).
$1\ L_\odot = 3.84 \times 10^{26}$ W

Measuring distance using standard candles

For distances which are too large to measure using parallax, astronomers use 'standard candles'.

Light sources which are further away appear fainter because the light is spread out over a greater area. If we know how luminous a source really is, then we can estimate its distance from how bright it appears from Earth.



The light which reaches Earth has spread out over a **sphere**.

radius of sphere = distance to earth, r

Surface area of sphere = $4\pi r^2$

On Earth, the received power per unit area is then

$$\text{received power per unit area} = \frac{\text{source luminosity}}{\text{area of sphere}}$$

$$F = \frac{L}{4\pi r^2}$$

The larger the distance, the smaller the power that we measure.

Astronomers traditionally measure the received power per unit area in **magnitudes,** but watts per square metre (W/m^2) is also good.

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Types of standard candle

There are several types of 'standard candle' objects for which we can predict the luminosity from some other measurement. Two of the most important are Cepheid variable stars and type 1A supernovae.

1. Cepheid variables

Cepheid variables are a special type of star with a luminosity which varies on a regular cycle. Around 1908, Henrietta Leavitt discovered that the period of the variability was closely linked to the luminosity of the star.

So, if you time the variability of a Cepheid then you can predict its luminosity. And if you know its luminosity and how bright it appears from Earth, then you can calculate the distance.

Cepheids are used to measure the distance of galaxies out to about 30,000,000 parsecs (30 Mpc). Cepheids are what Edwin Hubble used to determine the distances of “nebulae” (ie. galaxies) and derive the Hubble law.

2. Type 1A supernovae



Supernovae occur when massive stars explode at the end of their lives. A white dwarf star in a binary pair with a red dwarf star steals mass from the red dwarf until it is too massive to support itself against gravity any more. Then its core collapses, starting a runaway nuclear reaction and a bright explosion. Because the collapse always happens at the same mass, the luminosity of the explosion is always the same. From this known luminosity we can estimate the distance.

Supernovae are very bright – often as bright as all the stars in a whole galaxy put together. Because they are so bright, we can see them at very great distances, up to around 10,000,000,000 parsecs.

The disadvantage of supernovae as standard candles is that they don't hang around - you have to spot them when they go off, or shortly afterwards.